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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A01N 37/46

A1

(11) International Publication Number: WO 99/63819

(43) International Publication Date: 16 December 1999 (16.12.99)

(21) International Application Number: PCT/US99/12926

(22) International Filing Date: 8 June 1999 (08.06.99)

(30) Priority Data:
09/093,496 8 June 1998 (08.06.98) US

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(81) Designated States: CN, NO, NZ, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: PLANTS GROWN UTILIZING POLY (ORGANIC ACID) AS A NUTRIENT ABSORPTION ENHANCER

(57) Abstract

Plants are disclosed which are produced by the method of supplying polyamino acids, particularly polyaspartic acids, to the root zone or through foliar mechanisms. The plants of the invention demonstrate improved plant growth characteristics when compared to those not grown in the presence of polyaspartic acid, including, but not limited to: root growth, seedling vigor, increased yield, and early maturity.

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TITLE: PLANTS GROWN UTILIZING POLY (ORGANIC ACID) AS A NUTRIENT ABSORPTION ENHANCER

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. Serial No. 08/781,413, filed on January 10, 1997, now pending, which is a continuation-in-part of U.S. Serial No. 08/313,436, filed on September 27, 1994, now U.S. Patent No. 5,593,947, which is a continuation-in-part of U.S. Serial No. 07/972,375, filed on November 5, 1992, now U.S. Patent No. 5,350,735.

BACKGROUND OF THE INVENTION

Plants provide a great many benefits to mankind such as being a food source either directly through fruits, tubers, and grains or indirectly by nourishing the animals whose meat, milk or eggs we in turn consume. Plants also provide fibers such as cotton for use in clothing or fabrics. Also plants provide a myriad of environmental benefits such as habitats for wildlife, air purification and oxygen production, as well as providing soil conservation and ornamental design.

Farmers and other agriculturists strive to increase plant growth to better exploit the positive features of plants. A goal of agriculture has thus been to create plants which exhibit increased top growth, root growth, fruit load and yield. Plant growth is a complex process which is influenced greatly by environmental factors such as heat, moisture, and nutrients. One of the main limiting factors to the growth of plants is the soil nitrogen supply. This is evidenced by increased plant growth rate in response to nitrogen fertilizer. However, once the nitrogen supply is rectified, some other nutrient, such as phosphorus or potassium, may become the limiting factor.

The level of mineral nutrients naturally present in soil depends on the mineral content of its parent materials and its history during evolution as a soil. With very few exceptions, soils contain insufficient amounts, in forms available for uptake by plants, of the macronutrients nitrogen, phosphorus,

and potassium to sustain maximum growth rate, hence the practice of applying fertilizers containing these nutrients. See J.C. Forbes & R.D. Watson, Plants in Agriculture 188 (Cambridge University Press 1992).

Organic acids and oligomers thereof have been shown to promote plant growth. Typical such promoters of plant growth are described by Kinnersley et al., Plant Growth Regulation 9:137-146 (1990), which publication mentions the effects of lactic acid and relatively low molecular weight oligomers of lactic acid on plant growth. Similar description is found in U.S. Patent No. 4,813,997 to Kinnersley et al. (oligomers of glycolic and/or L-lactic acid) and U.S. Patent No. 4,799,957 to Danzig et al. (oligomers of thiolactic and thioglycolic acids). All of the foregoing approaches to plant growth promotion appear to focus on regulation as a means for increasing plant uptake of compounds vital to the growth of the plant, e.g., micronutrients such as calcium, magnesium, sulfur, manganese, zinc, copper, iron, boron, and the like.

A very common approach to the promotion of plant growth has been, and continues to be, the use of nutrients (fertilizers), natural as well as synthetic. The latter usually provides nitrogen in a plant-usable form, such as urea for example, and/or inorganic nitrates, phosphates, or the like compounds. While such nutrients may be applied, more or less, at the convenience of the farmer, and may be applied as often as deemed desirable, the overuse of synthetic nutrients and the inefficient use of synthetic nutrients are major factors responsible for environmental problems such as eutrophication of ground water, nitrate pollution, phosphate pollution, and the like. An overview of the undesirable effects of nitrogen fertilizer is presented by Byrnes, Fertilizer Research 26:209-215 (1990).

To ameliorate the problems attendant to inefficient nutrient use, it would be desirable and necessary for environmental and production reasons to improve the collection, absorption and consolidation of plant nutrients and hold them in a condition and position to maximize availability for plant uptake while minimizing loss of nutrients or fertilizer elements through leaching, denitrification, volitization and other mechanisms that distort or prevent

assimilation of these nutrients by plant biological and physical mechanisms. Poly (organic acid) and more preferably polyaspartic acid or its analogues, addresses these problems, and provides methods for collecting or attracting plant nutrients which results in more efficient usage of nutrients in the growing plant. For reasons not yet fully understood plants of the present invention when grown in the presence of polyaspartic acid, or its analogues, demonstrate more efficient uptake of nutrients in the soil, nutrients in fertilizer, and/or available water in soil.

Accordingly, it is a primary objective of the present invention to provide plants which when grown in the presence of poly (organic acid) or more preferably, polyaspartic acid or its analogues, demonstrate more efficient uptake of nutrients in the soil, nutrients in fertilizer, and/or available water in the soil.

Another objective of the present invention is to provide plants which express improved characteristics when grown in the presence of polyaspartic acid or its analogues, such improved characteristics including, but not limited to: improved top growth, improved plant vigor, increased root branches or root hairs, earlier maturity, improved harvest moisture, fruit load or increased yield.

Another objective of the present invention is to provide plants with enhanced drought-stress tolerance when grown in the presence of poly (organic acid) and more preferably polyaspartic acid or its analogues.

The method and means of accomplishing each of the above objectives will become apparent from the detailed description of the invention which follows. Additional objects and advantages of the invention will be set forth in part in the description that follows, and in part will be obvious from the description, or may be learned by the practice of the invention. The objects and advantages of the invention will be obtained by means of the instrumentalities and combinations, particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

According to the invention, plants are provided which exhibit greatly increased plant growth and productivity. This enhanced plant growth and productivity is demonstrated morphologically by increased growth rate, increased top growth, higher yields, higher fruit load, and quality, accelerated rate and improved quality of root formation (i.e. more root hairs, larger more developed root systems) and the like, is achieved by more efficient nutrient utilization by making available to the plant a higher level of plant food nutrients in the root feeding zone or through absorption and translocation through foliar mechanisms via a polyorganic acid, preferably a polymeric amino acid, most preferably polyaspartic acid, that is water soluble and not absorbed into the plant, i.e., having a weight average molecular weight (M/W) larger than 1500. Such polyaspartic acids are non-aromatic polymers that have at least 15 repeating amino acid units or mers in the polymer chain. The polyaspartic acid can be supplied to the plant directly or as a polysuccinimide which hydrolyzes in situ to polyaspartic acid.

Particularly preferred for the present purposes are polymeric amino acids such as polyaspartic acid or polysuccinimide alone or in combination with other polymers, e.g., polylactic acid, polyglycolic acid and the like, and other water-soluble polycarbocyclates, e.g. polyacrylic acid, polymelic acid, their copolymers and the like. Other water soluble polymers such as polyacrylamide and acrylamide-acrylic acid copolymers, either linear or cross linked, can also be used in combination with polyaspartic acids. Plants grown according to the invention have a distinct morphology and are distinctly different from plants grown using traditional botanical methods. These plants of the invention exhibit significantly more root hairs, improved yield, increased foliage etc.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows ears of corn after harvest, one treated with two quarts per acre of polyaspartic acid (PA) with starter fertilizer, another treated with just starter fertilizer and a third receiving neither starter fertilizer nor PA.

Figure 2 shows a field of corn at tasseling where one side received PA plus fertilizer and the other side received fertilizer alone.

Figure 3 shows the same field of corn in Figure 2 just before harvest where one side received PA plus fertilizer and the other side received just fertilizer.

Figure 4 shows two cotton plants, one grown with PA plus fertilizer and the other grown with just fertilizer.

Figure 5 shows roots of cotton plants treated with PA and fertilizer versus roots of cotton plants that received only fertilizer.

Figure 6 shows a field of cotton demonstrating the yield difference between cotton plants grown in the presence of PA plus fertilizer and cotton plants grown in the presence of fertilizer alone.

Figure 7 shows wheat heads treated with fertilizer and PA plus fertilizer.

Figure 8 shows roots of wheat plants, one without PA and the other with PA plus nutrient.

Figure 9 shows a cross section of peppers, one treated with only fertilizer and the other treated with PA plus fertilizer.

Figure 10 shows a series of pepper plants, one grown without a treatment of PA while the plants on the right were treated with three quarts per acre of PA.

Figure 11 shows the peppers on the left were the untreated group and the peppers on the right received a treatment of PA.

Figure 12 shows cabbage plants, where the cabbage on the left received PA plus fertilizer while the cabbage on the right received just fertilizer.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention provides for plants with increased plant growth and productivity resulting from the introduction of polyorganic acids such as the polymeric amino acid, polyaspartic acid. The present invention provides for plants exhibiting improved physiological morphological traits including: increased top growth, increased root growth, improved fruit load and higher yields.

Plant growth and development in the whole plant is in some ways programmed. All growth phases require water and nutrients which must be directed from where they are absorbed, manufactured or stored to the sink where they are needed at any one time.

The site from which a mineral or organic nutrient moves in the plant is a source where it has been absorbed, manufactured or stored there. Roots absorb water and minerals, actively photosynthesizing leaves are sources of carbohydrates and organic nitrogen compounds such as amino acids, and senescent organs within the plant are sources of many types of nutrient. These nutrients are directed along the xylem and phloem translocation systems to be utilized or stored at their destinations, which are known as sinks.

The main sinks are developing structures such as young leaves and roots, flowers, fruits and seeds, and storage organs. A single organ may be a source of one nutrient at the same time a sink for others.

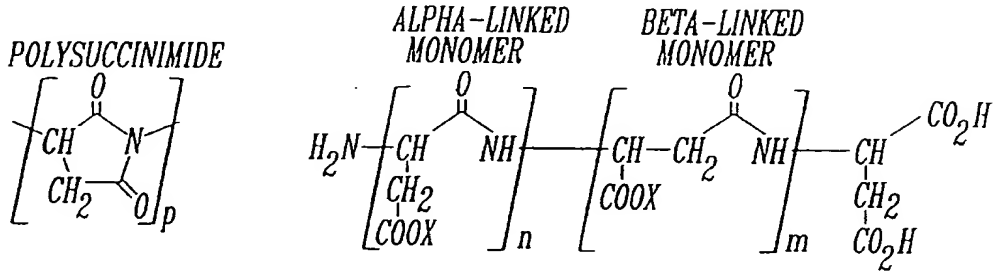
The rate of growth of a sink such as a fruit or storage organ and the final size it can attain are determined, to a considerable extent, by the rate at which water and nutrients are supplied to it. The rate at which nutrients are supplied is not likely to be limited by the rate of translocation. Changes in the sink, however, can have a pronounced feedback effect on the sources. For example, an increase in sink capacity often induces an increase in the strength of the source.

The direction of nutrients, then is controlled largely by sink demand, rather than by the output of sources or the ability of the phloem and xylem to

translocate. By ensuring that adequate nutrients are available to the sources, such as roots, the present invention allows for plants with improved traits in both sink and source of plants. By ensuring that the soil or growth medium supplies adequate nutrients and that the adsorbtion of these nutrients is increased, the present invention reduces the possibility that nutrients are a limiting factor, the plants of the present invention exhibit surprisingly improved physiological and morphological traits as described above.

The present invention is premised upon the fact that it has been discovered that certain compounds, mainly certain poly (organic acids), as set forth in earlier commonly owned United States Patent 5,350,735, which, along with each of its continuation-in-part application namely U.S. Patent No. 5,593,947 filed on September 27, 1994 and Serial No. 08/781,413 filed on January 10, 1997, all of which disclosures are incorporated herein by reference, can be used effectively in enhancing the nutrient absorption of a plant and result in a plant with increased root hairs, improved yield and more foliage than plants without such treatment.

Polysuccinimide and polyaspartic acids useful in this invention are represented by the following structures:



where p=10-1,000; $X=H^+$, Na^+, $NH4^+$, K^+, Ca^{++}, Mg^+, Zn^{++}, Co^+, Li^+, Ba^{++}, Fe^{++} and Fe^{+++}; $n+m \geq 15$.

The polyaspartic acid moieties contain aspartic acid monomer units linked by α peptide and β peptide bonds. A preferred polyaspartic acid is β-polyaspartic acid, i.e., one having >50 mole % of aspartic acid units linked by β peptide bonds and <50 mole % of aspartic acid units linked by α peptide bonds. Preferably, 60-80 mole % of the polyaspartic acid is in β-linkage form and the polyaspartic acid has a MW within the range of 2000-100,000. More preferably, approximately 70 mole % to 80 mole % of the polyaspartic acid has β form and has a MW within the range of 2000-30,000. Most preferably, approximately 70 mole % to 75 mole % of the polyaspartic acid has β form and 25 mole to 30 mole % α, and has a MW within the range of 2000-5000.

The present invention, in its various aspects, is predicated on the discovery that poly (organic acids) that are of a too large molecular size to enter a plant but can nevertheless, within their entity, collect, attract and hold chemical molecules (nutrients) so as to make them efficient to the plant in a more available and ready manner, thereby allowing plant growth with a more efficient use of applied and natural chemical materials. The more efficient utilization of such nutrients can be realized in the presence of the polymeric amino acid in as much as relatively lower nutrient dosages can be relied upon to provide the requisite nutrients to the plant.

In one embodiment, the polymeric organic acids can be made available to the plant as nutrient solutions containing at least about 1 part per million (ppm) by weight, preferably about 1 to about 50,000 parts per million (ppm) by weight, more preferably about 6,000 to about 50,000 ppm by weight of the polymeric amino acid in the solution. Such solutions can be applied to the soil surrounding the plant so as to contact the plant's root system, can be applied to the plant's foliage utilizing usual foliar feeding techniques, can be introduced into hydroponic gardening or farming systems, or in any other convenient manner to one skilled in the art. Solutions containing the polymeric amino acid can be sprayed or otherwise applied to contact the roots, stems, or leaves of the plants whose growth and/or development is to be enhanced, as well as to the seeds or reproduction parts of these plants, in an amount as is discussed in greater detail herein below. Solutions containing poly (organic acid) such as a polymeric amino acid are also useful to enhance effective plant growth under growth limiting conditions, e.g., in soil that contains salts in concentrations normally toxic to plants, soil depleted in certain nutrients, etc.

The polymeric amino acids such as polyaspartic acid can also be applied to soil in solid form alone or in combination with nutrients. Granular, pelletized, dust or powdered forms of the polyamino acids can be applied by gravity or air blast equipment into the furrow, row or site at seeding or planting time. Dry granular or pelleted forms of the polyamino acids such as polyaspartic acid can be impregnated or pre-formed as carriers of nutrients and can then be used for surface application by ground rig or aircraft. An example of such a pelletized form is polyaspartate coated on clay, sold under the trade name AmiSorb-10G by Donlar Corporation.

The polymeric amino acids can be applied to soil as a solid in the anhydro form as for example anhydropolyaspartic acid (polysuccinimide). Polysuccinimide can be mixed with sodium carbonate or sodium bicarbonate and applied as a powder, as a dry granule or in pellet form. The sodium carbonate and sodium bicarbonate will hydrolyze polysuccinimide to

polyaspartic acid sodium salt in moist soil. Polysuccinimide can also be applied to soil as a powder, pellet or as granules mixed with limestone (Ca and Mg carbonate). In this application the carbonates of the limestone can hydrolyze the polysuccinimide to polyaspartic acid sodium salt in moist or wet soil. Another way of using polysuccinimide is to apply it to soil as a powder, granule or pellet after the soil has received an injection of ammonia. In this process, ammonium hydroxide formed from the ammonia and water in the soil will hydrolyze the polysuccinimide to polyaspartic acid.

The polymeric amino acids, to be suitable for the practice of the present invention, must be or become water soluble, non-aromatic, and must have a molecular size sufficiently large to preclude absorption into the plant's own system if applied to the soil or plant foliage. To that end, the non-aromatic polymeric organic acids deemed suitable for the present purposes, while hydrophilic, have a weight average molecular weight (MW) larger than 1,500 and have at least about 15 repeating organic acid units (residues), or mers, in the linear polymer chain that constitutes the polymeric acid. Such linear polymer chains can be cross-linked, if desired, but only to a degree that does not materially affect the water solubility of the polymeric moiety. Polymeric organic acids having a molecular size in excess of MW about 100,000 usually do not exhibit adequate solubility in water for the present purposes, thus for present purposes a polymeric amino acid molecular size not larger than MW about 100,000 is preferred. Particularly preferred molecular size is in the range of MW about 2,000 to about 30,000.

Illustrative are polymeric amino acids, with or without carboxylic acid, thiocarboxylic acid, mercapto, hydroxy, imidocarboxy, and/or amino side chains, such as, for example, polylysine, polyglutamic acid, polysuccinimide, polyaspartic acid, polyglycine, polycysteine, polycysteine/glutamic acid, polyserine, polycysteine/glutamic/aspartic acid, mixtures of the foregoing, and the like. Block or random copolymers or terpolymers of several amino acids are also within the purview of the present invention as the polymeric acid component thereof. For example, the utilized polymeric acid component can be

a block copolymer of aspartic acid residues and L-lactic acid residues, a random copolymer of aspartic acid residues and glycolic acid residues, a conjugated protein constituted by amino acid residue chains interconnected by one or more polycarboxylic acid residues, a copolymer containing succinimide residues and partially hydrolyzed polysuccinimide. The polymeric amino acids can be used in combination with other water soluble organic polymers to provide more efficient utilization of both natural and synthetic plant growth nutrients. Examples of water soluble polymers which can be used are polylactic acid, polyglycolic acid, polyacrylic acid, polymaleic acid, polyacrylamide, acrylamide-acrylic acid copolymers, poly (vinyl alcohols), acrylamide/2-acrylamido-2-methylpropanesulfonic acid copolymers, acrylamide/daillyldimethylammonium chloride copolymers, acrylamide/dimethylaminoethyl methacrylate and acrylate copolymers and methyl chloride or sulfate quaternized derivatives of these copolymers, polyvinylpyrrolidone, acrylic acid/maleic acid copolymers, polyitaconic acid, acrylic acid/itaconic acid copolymers, maleic acid/itaconic acid copolymers, polymethacrylic acid, methacrylic acid/acrylamide copolymers and methacrylic acid/acrylic acid copolymers.

The water soluble polymers which can be used in combination with the polyamino acids should have a molecular size larger than MW of 1500 and have at least about 15 repeating organic monomer units, or mers, in the linear polymer chain that constitutes the water soluble polymer to be applied to the soil or the plant foliage. Such linear polymer chains can be cross-linked, if desired, but only to a degree that does not materially affect the water solubility of the polymeric moiety. For present purposes, a water soluble polymer of molecular size not larger than MW of about 100,000 is preferred. Particularly preferred molecular size is in the range of MW about 2,000 to about 30,000. Polymeric amino acids for use in the present invention can be made, inter alia, by thermal condensation methods. See, for example, U.S. Patent No. 5,057,597 to Koskan, U.S. Patent No. 5,221,733 to Koskan et al.;

U.S. Patent No. 5,219,952 to Koskan et al.; Little et al., American Chemical Society 97:263-279 (1991), and U.S. Patent No. 4,696,981 to Harada et al.

The starting materials for the polymerization, i.e., the amino acids, can exist as optical isomers, depending upon their respective structures, and can be polymerized either as a racemic mixture or as segregated optical isomers.

Hydrophobic polymeric amino acids such as polyalanine or other non-hydrolyzed water insoluble polyamino acids are not suitable for application to the soil or the plant foliage.

Particularly well suited for the practice of the present invention are the non-chelating polyamino acids such as polyaspartic acid having a molecular weight (MW) in the range of about 3,000 to about 100,000, polyglutamic acid having a MW in the range of about 4,000 to about 100,000, polyglycine having a MW in the range of 1,500 to about 7,000, and polylysine having a MW in the range of about 2,000 to about 7,000.

The presently contemplated polyamino acids are not chelating agents, and as such do not form chelates with the plant nutrients. Moreover, the presently contemplated polyamino acids are not considered plant growth regulators.

The aforesaid polyamino acids can function to increase the efficiency of utilization of nutrients, both natural and synthetic, by providing a nutrient attracting and collecting environment which allows more nutrients within the plant absorption zone to be available for uptake and utilization. The nutrients which are more efficiently utilized can be those found naturally in the soil or plant growing medium or those added to promote plant growth or residual nutrients from previous nutrient treatments. More efficient utilization by the growing plants of both macronutrients (N, P, K) and micronutrients (Ca, Mg, S, Zn, Fe, Mn, B, Co, Mo, Cu, Ni) is accomplished by employing the polyamino acids of this invention.

The plants of the present invention can be grown for many uses and in a variety of mediums. Illustrative are uses in agriculture, gardening,

horticulture, hydroponics, forestry, land reclamation (e.g., landfills, soils with relatively high salt concentration, etc.), and the like.

One embodiment of the present invention are plants grown in crop or production uses as grain crops, cotton, or flowering nursery crops. Suitable dosage rates for soil treatment with a polymeric amino acid component of the present invention, so as to provide a sufficient polymeric amino acid to the plant to collect and hold nutrients in the plant utilization range are about 2 to about 500 ounces of the polymeric amino acid per acre. Crops with an abundance of foliage, such as wood crops, grain crops, cotton, etc., usually are treated at dosage rates at an intermediate range, that is, about 25 to about 250 ounces per acre. Relatively lower dosage rates within the foregoing or overall range, that is, about 2 to about 25 ounces per acre, are usually sufficient for agricultural row crops, flowering nursery crops, and the like.

Table 1 below demonstrates the preferred dosage rates of polyaspartic acid for best results and improved yield response for cotton, corn, vegetables and winter wheat. Note that with irrigation, it is better to use the higher rate in the specified range of polyaspartic acid or its analogues for the appropriate crop.

Table 1: Application of Polyaspartic Acid (PA) or its Analogues

Crop:	**Application rate of PA**	**For best results**	**Average yield response**
Cotton	about 2.0-4.5 lbs. PA/acre	Apply half of rate at planting with banded fertilizer and half with side-dress fertilizer	Up to 200 pounds of lint per acre
Corn	about 1.0-2.5 lbs PA/acre	Apply half of rate at planting with banded fertilizer and half with side-dress fertilizer	About 7 to 10 bushels/acre with about 1 to 2 points less amoisture at harvest
Vegetables	about 1.0-2.5 lbs PA/acre	Apply AmiSorb with fertilizer - half banded at planting and half applied with side-dressed nutrients	Up to 15% more yield, about 5 to 10 days earlier maturity
Winter wheat	about 1.0-2.5 lbs PA/acre	Apply 1 lb with fall fertilizer and about 1 lb at top dress	About 7 bushels per acre, and about 1 to 2% points less moisture at harvest

The polymeric amino acid can be made available to the plant as a separate treatment, or in combination with other water soluble polymers or in combination with other nutrients. Solid as well as liquid dosage forms can be utilized for this purpose, e.g., aqueous solutions, solid soil conditioning substances such as particulate clays bearing the polymeric amino acid commingled with nutrient components, solid particulate admixtures of polymeric amino acid, nutrient and the like.

The polymeric amino acid can be made available to the plant in the anhydro form as for example anhydropolyaspartic acid (polysuccinimide) in combination with a basic material which in the presence of water, soil moisture, rainfall, etc. can hydrolyze polysuccinimide to polyaspartic acid or salts. Basic materials which can be used are sodium carbonate, sodium bicarbonate, limestone, ammonia and the like. Polysaccinimide can be applied and mixed with the solid basic material in powder, pellet or granule form. Similarly, powder, pellet or granule form of polysuccinimide can be applied to soil after an injection of ammonia has been done.

As stated above, a polyamino acid which is well suited for the practice of this invention, to provide more efficient utilization of both natural and synthetic plant growth nutrients, is polyaspartic acid. This polymer can be conveniently prepared from L-aspartic acid, D-aspartic acid or DL-aspartic acid, or from aspartic acid precursors (ammonium maleate, maleamic acid, ammonium malate, diammonium maleate, diammonium malate, ammonium maleamate, ammonium fumarate, diammonium fumarate) using thermal condensation methods.

Plants grown in the presence of polyaspartic acid and its analogues are able to demonstrate enhanced uptake of macro and micro nutrients enabling the plants to mature earlier and reach higher yields. Plants demonstrating improved performance in the presence of polyaspartic acids and its analogues include a variety of row and cash crops such as wheat, corn, cotton, soybeans and vegetables.

The polyaspartic acid or its analogues rapidly attracts or absorbs cations present in soil or soil containing liquid fertilizers or dissolving solid fertilizers. These cations include the positively charged ions required for plant nutrition, such as: potasium, K^+; ammonium, NH_4^+; calcium, Ca^{++}; magnesium, Mg^{++}; zinc, Zn^+; maganese, Mn^{++}; copper, Cu^+; Zn^{++} and iron, Fe^{++}. Anions such as phosphate ($H_2P0_4^-$ and HPO_4^{--}); nitrate (NO_3^-); chloride (Cl^-); and sulphate (SO_4^{--}) may also be attracted to the polyaspartic acid or its analogues through a process known as ionic double layer. In this situation, the negatively

charged anion share some positive charges of cations such as calcium and magnesium with the polymer. Concentrating nutrient cations and anions along the polymer creates points of high nutrient concentration. When this high nutrient concentration is in the soil, roots come into contact with the polymer molecule. That point on the root surface is also effected by the large amount of water associated with the polymer molecules. The combination of high nutrient concentrations and water enhances the movements into the plant roots at that point.

Increased uptake of cations such as potasium and amonium, both with a single positive charge, may provide a positive influence on uptake of phosphate. The effects of amonium and potasium on phosphate uptake are well understood. When positively charged ions move into the root, electrical neutrality is maintained by the root through releasing positive charges in the form of hydrogen anions thus creating soil acidity. That means that the pH near the root surface tends to decline. Also, anions such as phosphate, nitrate, chloride and sulfate are taken up along with the cations as another means of maintaining electrical neutrality.

Plants grown in the presence of polyaspartic acid or its analogues demonstrate improvements in top growth, root growth, fruit load, and yield. The differences will be clear to one of ordinary skill in the art. Improved top growth in plants grown in the presence of polyaspartic acid or its analogues can be evidenced by taller, more vigorous plants, increased foliage and slightly advanced maturity. Plants may be 2-4 inches taller in mid to late season, depending on the crop.

Improved root growth in plants grown in the presence of polyaspartic acid and its analogues can be evidenced by increased root growth, particularly when polyaspartic acid has been applied with starter fertilizer to the growing medium. In crops that have a tap root, a longer root, typically 2-3 inches longer and a more extensive lateral root system, including an extensive system of root hairs, are present. In fibrous root crops the improved growth can be evidenced by a longer, thicker, more dense root system.

Improvements in fruit load for plants grown in the presence of polyaspartic acid or its analogues can be observed because plants with better nutrition, set and fill more grain, fruit, bolls, etc. For example, cotton plants of the present invention when grown in the presence of fertilizer yield about 227-415 pounds lint per acre more than other cotton plants grown in the presence of the same fertilizer conditions. Similar experiments comparing tomato plants of the present invention to other similarly adapted tomato plants show the tomato plants of the present invention exhibit an approximately 4 ton per acre advantage in yield of fruit.

A high yielding crop requires more nutrients, therefore, to obtain the full yield benefit of growing a plant in the presence of polyaspartic acid or its analogues, it is best to supply adequate plant nutrients to meet the late season needs of the plant. Finally, improved yield of plants grown in the presence of polyaspartic acid or its analogues can be evidenced through weight data from a mechanical harvest or hand picking 1/1000th of an acre in several places in a representative area of the field and then weighed. Increases are surprisingly high; for example, corn plants of the present invention have shown about a 9-15 bushel per acre increase when grown in the presence of polyaspartic acid and fertilizer over corn plants grown in the presence of fertilizer alone. Increases as high as 19-61 bushels per acre have been achieved. When looking at corn silage grown under the same conditions an increase of about two tons is demonstrated. Maturity effects can be observed at this time also as evidenced by final stands, harvest moisture, etc. Plants grown in the presence of polyaspartic acid and its analogues also tend to be advanced in maturity. The increased yield and advanced maturity of the present invention is shown across many different crops such as corn, soybean, cotton, wheat, vegetable crops and other crops, such as sorghum and sugar beet.

DEFINITIONS

The term polyaspartic acid (PA) used herein also includes salts of polyaspartic acid. Counterions for polyaspartic include, but are not limited to,

the alkaline and alkaline earth cations some examples of which are Na^+, K^+, Mg^{++}, and Li^+, Ca^{++}, Zn^{++}, Ba^{++}, Co^{++}, Fe^{++} and Fe^{+++}, and NH_4^+.

Polysuccinimide is the imide form of polyaspartic acid and is also known as anhydropolyaspartic acid.

The term "chelate," as used herein in its various forms, refers to a complex formed by a polydentate ligand, i.e., a ligand that supplies more than one pair of electrons to a cation. See for example, Masterson et al., *Chemical Principles*, 6th ed., Saunders College Publishing Co., Philadelphia, Pa. (1985), p. 635.

Similarly, the term "chelating agent," as used herein in its various forms, refers to a ligand that possesses at least two pairs of unshared electrons which pairs are far enough removed from one another to give a ring structure with a stable geometry. Ibid, p. 638.

The term "top growth" as used herein refers to the biomass of the plant above the soil level or other than the root systems, including stems, branches, foliage, and the like.

The term "root growth" as used herein refers to the biomass of the plant below the soil line or in contact with the growth medium, including tap root, root branches, root hairs and the like.

The term "fruit load" as used herein refers to the fruiting bodies of a plant as measured by quantity of fruiting bodies per plant (set) and the size of the fruiting bodies (fill). Examples of fruiting bodies include, but are not limited to, tomatoes, melons, peppers, and the like.

The term "yield" as used herein refers to the harvestable biomass of a plant. This harvestable biomass includes grain, flax, fruit, tubers and the like.

The term "crop" as used herein refers to many plants growing together, wherein the plants interact with each other as well as with the environment. The plants in a crop are usually grown for a purpose, such as food production or fiber production, and the plants are selected for this purpose.

The term "vegetable crop" as used herein refers to plants raised primarily for the purpose of consuming the edible portion such as the leaf, root,

or fruiting body. Vegetable crops include, but are not limited to, carrot, sweet corn, celery, broccoli, cabbage, potato, pumpkin, lettuce, pepper, spinach, tomato, and the like.

The term "cash crop" as used herein refers to crops grown especially for sale and are usually selected for their ability to produce income. Cash crops include, but are not limited to, such crops as cotton, soybean and wheat.

The term "row crops" as used herein refers to crops routinely grown in fields in a row formation, including, but not limited to, corn.

EXAMPLES

The present invention is further illustrated, but not necessarily limited, by the following examples which demonstrate more efficient utilization of plant growth nutrients by the presence of polyaspartic acid (PA). Examples 1-6 were conducted in 1996 utilizing data collected from proprietary private research as well as university plots, governmental agency plots and professional crop consultants throughout the United States and Canada. These studies were conducted to evaluate the effects of polyaspartic acid on plants grown in the presence of polyaspartic acid focusing mainly on the traits of growth and yield. Examples 1-6 contain information based on this research, in close to a million acres of dealer and farmer test plots. It will be apparent to those of ordinary skill in the art that certain modifications can be made to the composition and process without departing from the spirit and scope of the invention herein described. It is to be further understood that all citations to articles, patent applications, patents, etc., herein are hereby expressly incorporated by reference.

EXAMPLE 1

Corn Plants Grown in the Presence of Polyaspartic Acid Versus Corn Plants Grown Without the Presence of Polyaspartic Acid

Corn

Seven trials in Maryland, Illinois, Kentucky and Kansas were conducted comparing corn plants grown in the presence of polyaspartic acid plus fertilizer to the same corn varieties planted with fertilizer alone. The increase in yield from all university trials was in the range of 5 bushels per acre increase to 19 bushels per acre increase. The average increase from all university trials in corn is 15 bushels per acre increase when using polyaspartic acid plus fertilizer versus fertilizer alone.

Table 2

Location:	**Fert. Alone**	**PA + Fert.**	**Diff.**	**Rate**	**Application Method**	**LSD (.05)**
Maryland	128 bu/A	140 bu/A	12	1.06	With Starter	10.8
Average increase for this application method is 12 bu/A						
Illinois	135	151	16	2.12	Banded between rows & incorporated	9.9

Average of 3 hybrids						
Illinois	135	149	14	2.12	Banded between rows & un-incorporated	9.9
Average of 3 hybrids						
Illinois	135 bu/A	141 bu/A	6	2.12	Banded over row	9.9
Average of 3 hybrids						
Maryland	146	151	5	2.12	Broadcast with UAN	4.66
Average increase for this application method is 5 bu/A						
Kentucky	79	98	19	2.12	Split applied preplant/post with dry fertilizer nitrogen	Sig @0.10
Average increase for						

this application method is 19 bu/A						
Kansas	213	226	13	2.12	With starter	12
Maryland	128	134	6	2.12	With starter	5.7 (LSD @ 0.15)
Average increase for application method is 9 bu/A						

Looking at data from replicated farm trials, the average increase for plants grown in the presence of polyaspartic acid compared to corn plants not grown with polyaspartic acid is in the range of 19 bushels per acre to 61 bushels per acre. The average increase for significant replicated farms is 41 bushels per acre (Table 3).

TABLE 3

Location:	**Fert. Alone**	**PA + Fert.**	**Diff.**	**Rate lb PA per acre**	**Application Method**	**LSD (.05)**
Texas/New Mexico	239 bu/A	275 bu/A	36	2.12	Broadcast/irrigated	29
Average increase for application						

method is 36 bu/A						
Texas/New Mexico	211	233	22	2.12	Broadcast/starter	21
Average increase for application method is 22 bu/A						
Texas/New Mexico	200	260	60	2.12	Starter	26
Texas/New Mexico	171	200	29	2.12	Starter	19
Texas/New Mexico	218	256	38	2.12	Starter	27
Texas/New Mexico	196	239	43	2.12	Starter	23
Texas/New Mexico	225	268	43	2.12	Starter	32
Texas/New Mexico	166	223	57	2.12	Starter	30
Texas/New Mexico	192	253	61	2.12	Starter	18
Average increase for application method is 47 bu/A						
Kansas	197	216	19	2.12	Starter	16.2
Average						

increase for application method is 19 bu/A						

Data collected from non-replicated farm trials, as shown in Table 4, demonstrate that the average increase in bushels per acre ranges from 2 bushels per acre to 16 bushels per acre increase for corn plants grown in the presence of polyaspartic acid as compared to corn plants not grown in the presence of polyaspartic acid. The average increase for non-replicated farm trials in corn plants grown in the presence of polyaspartic acid is 9 bushels per acre.

TABLE 4

Application Method	**Rate lb PA/A**	**Average Increase**	**Number of Trials**
Broadcast with dry fertilizer	1.06 lb	2 bu/A	1
Side-dress	1.06	8	2
Starter	1.06	8	12
Not Reported	1.06	14	1
Average increase for 1.06 lb/A is 8 bu/A			
Not reported/irrigated	2.12	12	2
Starter/side-dress/irrigated	2.12	2	1
Broadcast	2.12	11	2
Broadcast with UAN	2.12	11	1
Broadcast/starter	2.12	2	1
Not reported	2.12	11	3

Side-dress	2.12	5	2
Starter	2.12	11	6
Average increase for 2.12 lb/A is 9 bu/A			
Broadcast with water		16	1
Not reported		8	2
Average increase for unknown rate is 10 bu/A			

A non-replicated field trial was also conducted to determine average increase of corn silage from corn plants grown in the presence of polyaspartic acid when compared to corn plants not grown in the presence of polyaspartic acid. The average increase from the non-replicated field trial in corn silage is two tons per acre when using polyaspartic acid plus fertilizer versus fertilizer alone.

Figure 1 demonstrates the maturity and yield as evidenced by ears of corn from plants grown with and without polyaspartic acid. The ear of corn on the left received a treatment of 2.12 pounds per acre of polyaspartic acid with starter fertilizer, the ear in the middle received just starter fertilizer, and the ear on the right received neither starter fertilizer nor polyaspartic acid. The polyaspartic acid treated ear is larger and more mature, thus providing evidence that corn plants grown in the presence of polyaspartic acid usually yield more than plants grown in the absence of polyaspartic acid. In addition, test results have shown that harvest moisture of corn plants grown in the presence of polyaspartic acid are usually 1 to 2 points dryer.

Figure 2 demonstrates the advantage that corn plants grown in the presence of polyaspartic acid plus fertilizer had at detasseling (shown on the right) versus the plants (on the left) that received just fertilizer. The corn plants grown in the presence of polyaspartic acid plus fertilizer on the right grew faster, more vigorously and tasseled sooner. This figure supplied further

evidence of earlier pollination, ear set and dry down of plants grown in the presence of polyaspartic acid.

The same field (from Figure 2) is shown just before harvest in Figure 3. The yields in this field were about 13 bushels higher in the area where plants were grown in the presence of polyaspartic acid. Additionally, plants grown in the presence of polyaspartic acid are usually two to three percentage points dryer. This higher yield and lower moisture level means more profit per acre for the farmer.

These tables and figures show that corn plants grown in the presence of polyaspartic acid produce excellent corn yield which is increased over that of corn plants not grown in the presence of polyaspartic acid. Corn plants grown in the presence of polyaspartic acid and fertilizer have demonstrated average increases in grain yield of 9 to 41 bushels per acre over that of corn plants grown in the presence of fertilizer alone. In addition, corn plants grown in the presence of polyaspartic acid and fertilizer demonstrate grain moisture at harvest 1 to 3 points less than corn plants grown with fertilizer alone.

EXAMPLE 2

Soybean

Research conducted in Missouri and non-replicated farm trials demonstrate that soybean plants grown in the presence of polyaspartic acid plus fertilizer (as compared to soybean plants grown in the presence of fertilizer alone) show an average increase of 10 bushels per acre (Table 5).

TABLE 5

Location:	Check	PA + Fert.	Diff.	Rate lb PA per acre	Application Method	LSD
Missouri	46 bu/A	56 bu/A	10	2.12	Broadcast with water	Sig @
Average increase for application method is 10 bu/A						

Research conducted in non-replicated farm trials demonstrate that soybean plants grown in the presence of polyaspartic acid plus fertilizer (as compared to soybean plants grown with fertilizer alone) demonstrate an average increase of 4 bushels per acre (Table 6).

TABLE 6

Application Method	Rate lb PA/A	Average Increase	Number of Trials
Banded with water	1.06	8 bu/A	1
Average increase for 1.06 lb/A is 8 bu/A			
Broadcast with water/irrigated	2.12	1 bu/A	2
Broadcast with water	2.12	1 bu/A	2
With starter	2.12	3 bu/A	1

Average increase for 2.12 lb/A is 1 bu/A			
Not reported		10 bu/A	1
Average increase is 10 bu/A			

EXAMPLE 3

Cotton

Research data collected from four different locations demonstrate that cotton plants grown in the presence of polyaspartic acid and fertilizer, when compared to cotton plants grown with fertilizer alone, demonstrate an average increase in pounds of lint per acre in the range of 236 pounds lint per acre to 376 pounds lint per acre. The average increase for cotton plants grown in the presence of polyaspartic acid plus fertilizer, when compared to cotton plant grown in the presence of fertilizer alone, is 227 pounds lint per acre (Table 7).

TABLE 7

Location:	**Fert. Alone**	**PA + Fert.**	**Diff.**	**Rate lbs PA/A**	**Application Method**	**LSD (.05)**
Lexington, MS	1362 lint/A	1,738 lint/A	376 lb	1.06	Broadcast	339
Average increase for application method is 376 lb. lint per acre						

Marianna, AR	1,104	1.140	36	1.06	Banded side-dress	sig
Merced, CA	1,221	1,458	237	2.12	Broadcast	wig
Tchula, MS	561	787	226	4.24	In furrow	sig
Average increase for application method is 226 lb lint per acre						
Tchula, MS	1,400	1,630	230	8.48	In furrow	sig
Average increase for application method is 230 lb lint per acre						

Cotton plants grown on replicated farm trials demonstrate an increase in pounds lint per acre for cotton plants grown in the presence of polyaspartic acid and fertilizer as compared to cotton plants grown with fertilizer alone. The range of average increases of cotton plants grown in the presence of polyaspartic acid over cotton plants without polyaspartic acid is a range of 228 pounds lint per acre to 686 pounds lint per acre. The average increase for replicated farm trials for cotton plants grown in the presence of polyaspartic acid is 415 pounds lint per acre (Table 8).

TABLE 8

Location:	**Fert. Alone**	**PA + Fert.**	**Diff.**	**Rate lb PA/A**	**Application Method**	**LSD (.05)**
Lubbock, TX	814 lb/A	1,366 lb/A	552	2.12	Irrigation with N	92
Idalou, TX	1,299	1,596	297	2.12	Preplant + starter	234
Brownfield, TX	543	1,229	686	2.12	Starter	191
Brownfield, TX	555	783	228	2.12	Side-dress N-P	169
Portales, NM	1,207	11,657	450	2.12	Preplant + side-dress	304
Average increase is 443 pounds of lint per acre						
Bonita, LA	780	1,056	276	2.12	with starter	141
Average increase for application method is 276 pounds of lint per acre						

Cotton plants grown in the presence of polyaspartic acid and fertilizer have produced excellent lint yield increases over cotton plants grown with

fertilizer alone. These lint yield increases of up to 200 pounds per acre or greater have frequently been recorded in field studies. Figure 4 demonstrates cotton plants grown in the presence of polyaspartic acid plus fertilizer demonstrate increased boll set. The plant on the left received only fertilizer and had 73 bolls, while the plant on the right received polyaspartic acid plus fertilizer and had 113 bolls. Figure 5 demonstrates cotton plants grown in the presence of polyaspartic acid typically have larger root systems and thereby take up more nutrients to the growing plant. In this figure, the plant on the left received only fertilizer, while the plant on the right received polyaspartic acid plus fertilizer. Figure 6 demonstrates the faster cotton maturity due to increased nutrient uptake of cotton plants grown in the presence of polyaspartic acid and fertilizer. The cotton field on the left received fertilizer alone, while the cotton on the right was grown in the presence of polyaspartic acid plus fertilizer.

EXAMPLE 4

<u>Wheat</u>

Trials comparing winter wheat grown in the presence of polyaspartic acid plus fertilizer versus winter wheat grown in the presence of fertilizer alone shows the wheat plant grown in the presence of polyaspartic acid plus fertilizer express a range of yield increase from 1 bushel per acre to 11 bushels per acre. The average increase from all university trials with winter wheat is 4 bushels per acre comparing plants grown in the presence of polyaspartic acid plus fertilizer to plants grown in the presence of fertilizer alone (Table 9).

TABLE 9

Location:	F rt. Alone	PA + Fert.	Diff.	Rate lb PA/A	Application Method	LSD (.05)
Kansas	48 bu/A	50 bu/A	2 bu/A	1.06	Top-dressed	2.2
Kansas	18	23	5	1.06	Top-dressed	3.4
Kansas	45	48	3	1.06	Top-dressed	2.5
Kansas	38	41	3	1.06	Top-dressed	2.1
Kansas	26	29	3	1.06	Top-dressed	2.7
Kansas	24	25	1	1.06	Top-dressed	0.7
Average increase for application method is 3 bushels per acre						
Kansas	47	58	11	2.12	Top-dress with fertilizer	5
Average increase for application method is 11 bushels per acre						
Virginia	73	79	6	2.12	Top-	4.7

					dressed split applied in Spring	
Average increase for application method is 6 bushels per acre						

Non-replicated farm trials showed that winter wheat grown in the presence of polyaspartic acid and fertilizer, versus winter wheat grown in the presence of fertilizer alone, demonstrate an average yield increase of 3 bushels per acre to 10 bushels per acre. The average increase of non-replicated farm trials is 8 bushels per acre (Table 10).

TABLE 10

Application Method	**Rate lb PA/A**	**Average Increase**	**Number of Trials**
Top-dressed	1.06	3 bu/A	1
Average increase for 1.06 lb/A is 3 bushels per acre			
Top-dressed	2.12	10 bu/A	2
Average increase for 2/12 lb/A is 10 bushels per acre			

Non-replicated farm trials were also conducted utilizing spring wheat. Spring wheat data was collected for spring wheat plants grown in the presence of polyaspartic acid plus fertilizer as compared to spring wheat grown in the

presence of fertilizer alone. Although only one trial was conducted, the average increase of non-replicated spring wheat farm trial is 10 bushels per acre for spring wheat grown in the presence of polyaspartic acid plus fertilizer over that of spring wheat grown in the presence of fertilizer alone (Table 11).

TABLE 11

Application Method	Rate lb PA/A	Average Increase	Number of Trials
Broadcast with dry fertilizer	2.12 lb	10 bu/A	1

The data reported in Tables 9-11 show that plants grown in the presence of polyaspartic acid produce higher wheat yields. Figure 7 helps demonstrate that wheat plants grown in the presence of polyaspartic acid and fertilizer increase the number of kernels per row as much as 14-18% and that the numbers of rows per head has increased as much as 30-52% over wheat plants grown in the presence of fertilizer alone. Figure 8 demonstrates the improved root system of plants grown in the presence of polyaspartic acid as compared to wheat plants not grown in the presence of polyaspartic acid. Figure 8 demonstrates that the plants on the right, grown in the presence of polyaspartic acid, exhibit increased area occupied by the plants roots, thereby resulting in greater availability of nutrients to the plant and increased yields.

EXAMPLE 5

<u>Vegetable Crops:</u>

<u>Peppers</u>

Peppers grown in the presence of polyaspartic acid as compared to pepper plants not grown in the presence of polyaspartic acid demonstrate an increased yield based on weight and number of peppers per plant. Figure 9 demonstrates peppers treated with polyaspartic acid (cross sections on the right) demonstrate as much as a 20% increase on a weight basis as peppers

plants grown without polyaspartic acid (cross sections on the left). Figure 10 demonstrates that peppers not treated with polyaspartic acid demonstrate a lower number of peppers per plant as compared to peppers grown in the presence of polyaspartic acid. The peppers grown in the presence of polyaspartic acid (on the right) yielded two to three peppers per plant as compared to only one pepper per plant on the control group (on the left). Finally, Figure 11 demonstrates that peppers grown without the presence of polyaspartic acid (control plants on the left) demonstrate slower plant growth than plants grown in the presence of polyaspartic acid (plants on the right).

Cabbage

Cabbage grown in the presence of polyaspartic acid plus fertilizer demonstrates an increase in yield up to 15% and a 5-7 day earlier maturity than plants grown without polyaspartic acid. In Figure 12, the cabbage on the left was grown in the presence of polyaspartic acid plus fertilizer while the cabbage on the right received just fertilizer. The cabbage grown in the presence of polyaspartic acid plus fertilizer is larger and more fuller.

Lettuce

Results from lettuce trials grown in California demonstrate that lettuce plants grown in the presence of polyaspartic acid plus fertilizer as compared to lettuce plants grown with fertilizer alone demonstrate a 139 gram per head weight advantage. (Table 12).

TABLE 12

Location:	Fert. Alone	PA + Fert.	Diff.	Rate lb PA/A	Application Method	LSD (.05)
California	474	613	139	3.18	Side-dress	76
	grams per head wt	grams per head wt				
Average increase is 139 grams per head						

Carrot

The data in Table 13 demonstrate that carrots, when grown in the presence of polyaspartic acid plus fertilizer as compared to carrots grown in the presence of fertilizer alone, demonstrate an average increase in yield of 17 tons per acre.

TABLE 13

Application Method	Rate lb PA/A	Average Increase	Number of Trials
Broadcast with fertilizer six weeks after planting	1.06 lb	17 ton/A	1

Potato

The data in Table 14 are from non-replicated field trial results conducted in 1996. The results show that potatoes grown in the presence of polyaspartic acid plus fertilizer, when compared potatoes grown in the

presence of fertilizer alone, demonstrate an average increase in yield of 44 cwt. per acre.

TABLE 14

Application Method	Rate lb PA/A	Average Increase	Number of Trials
Broadcast with water	2.12	23 cwt/A	1
Not reported	2.12	48 cwt/A	3
Starter	2.12	55 cwt/A	1
Average increase for non-replicated farm trials is 44 cwt/A			

Pumpkin

Non-replicated field trial data shows that pumpkins grown in the presence of polyaspartic acid plus fertilizer, versus pumpkins grown in the presence of fertilizer alone, demonstrate an average increase in yield of 6 tons per acre (Table 15).

TABLE 15

Application Method	Rate lb PA/A	Average Increase	Number of Trials
Broadcast with water	2.12	6 tons/A	2

Sweet corn

A non-replicated field trial demonstrates that sweet corn grown in the presence of polyaspartic acid plus fertilizer, when compared to sweet corn grown in the presence of fertilizer alone, demonstrates an average yield increase of sweet corn of 520 pounds per acre (Table 16).

TABLE 16

Application Method	Rate lb PA/A	Average Increase	Numb r of Trials
Broadcast with UAN	1.06	520 lb/A	1

Tomato

Private research results show that tomato plants grown in the presence of polyaspartic acid plus fertilizer, when compared to tomato plants grown in the presence of fertilizer alone, demonstrate an average increase of 4 tons per acre (rate in application method not available)(Table 17).

TABLE 17

Location:	Fert. Alone	PA + Fert.	Diff.	Rate lb PA/A	Application Method	LSD (.05)
California	12 ton/A	16 ton/A	4 Ton/A			2.21

Celery

The results of a private research trial demonstrate that celery grown in the presence of polyaspartic acid plus fertilizer, when compared to celery grown with fertilizer alone, demonstrates an average increase in celery yield of 200 grams per harvested plot (Table 18).

TABLE 18

Location:	Fert. Alone	PA + Fert.	Diff.	Rate lb PA/A	Application Method	LSD (.05)
California	801 gm/plot	1,001 gm/plot	200 gm/plot	3.18	Drip irrigation	132.4

Farm trial results for celery show that celery grown in the presence of polyaspartic acid plus fertilizer, when compared to celery grown in the presence of fertilizer alone, demonstrates an average increase of 200 boxes per acre (Table 19).

TABLE 19

Location:	**Fert. Alone**	**PA + Fert.**	**Diff.**	**Rate lb PA/A**	**Application Method**
Texas	1,300 boxes/A	1,500 boxes/ A	200	3.18	With starter
Average increase for application is 200 boxes/acre					

Broccoli

Private research results, comparing broccoli plants grown in the presence of polyaspartic acid plus fertilizer versus broccoli plants grown in the presence of fertilizer alone, demonstrate an average increase of 32 grams per harvested plot (Table 20).

TABLE 20

Location:	Fert. Alone	PA + Fert.	Diff.	Rate lb PA/A	Application Method	LSD (.05)
California	130 gm/plot	168 gm/plot	38	3.18	Side-dress	22.5
California	130 gm/plot	156 gm/plot	26	6.36	Split preplant & side-dress	25.9

As can be seen from the figures and tables above, vegetable plants grown in the presence of polyaspartic acid plus fertilizer demonstrate excellent yield increases over vegetable plants grown in the presence of fertilizer alone. Yield increases of 10-20% have been recorded in field studies when comparing vegetable plants grown in the presence of polyaspartic acid plus fertilizer versus vegetable plants grown in the presence of fertilizer alone. Also, an earlier maturity of typically 5-10 days has been observed.

EXAMPLE 6

Additional Crops:

Sorghum

1996 research results show that sorghum plants grown in the presence of polyaspartic acid plus fertilizer, when compared to sorghum plants grown in the presence of fertilizer alone, showed a range of average yield increase from 2 bushels per acre to 9 bushels per acre. An overall average yield increase was calculated to be an average increase of 4 bushels per acre (Table 21).

TABLE 21

Location:	Fert. Alone	PA + Fert.	Diff.	Rate lb PA/A	Application Method	LSD (.05)
Kansas	100 bu/A	103 bu/A	3	1.06	With Starter	1.4
Average increase for this application method is 3 bu/acre						
Kansas	88	91	3	2.12	Broadcast	1.8
Kansas	95	104	9	2.12	Broadcast	1.8
Average increase for this application method is 6 bu/A						
Kansas	95	101	6	2.12	Starter	1.8
Kansas	100	102	2	2.12	Starter	1.8
Kansas	100	102	2	2.12	Starter	1.8
Kansas	88	90	2	2.12	Starter	1.8
Average increase for this application method is 3 bu/A						

1996 replicated field trial results showed that sorghum plants grown in the presence of polyaspartic acid plus fertilizer demonstrated an average increase of 31 bushels per acre over sorghum plants grown in the presence of fertilizer alone (Table 22).

TABLE 22

Location:	Fert. Alone	PA + Fert.	Diff.	Rate lb PA/A	Application Method	LSD (.05)
Kansas	55 bu/A	86 bu/A	31	2.12	With starter	4.8

Peanut

Non-replicated field trial studies show that peanuts grown in the presence of polyaspartic acid plus fertilizer demonstrate an average increase of 209 pounds per acre when compared to peanuts grown in the presence of fertilizer alone (Table 23).

TABLE 23

Application	Rate lb PA/A	Average Increase	Number of Trials
Not reported	2.12	209 lb/A	2

Spring Barley

A non-replicated field trial, comparing spring barley plants grown in the presence of polyaspartic acid plus fertilizer and spring barley plants grown in the presence of fertilizer alone, showed an average increase of 6 bushels per acre for the plants grown in the presence of polyaspartic acid (Table 24).

TABLE 24

Application	Rate lb PA/A	Average Increase	Number of Trials
Broadcast with liquid fertilizer	1.06	6 bu/A	1

Sugar Beet

Data from non-replicated field trials demonstrate that sugar beets grown in the presence of polyaspartic acid plus fertilizer, when compared to sugar beets grown in the presence of fertilizer alone, exhibit an average increase of 4 tons per acre (Table 25).

TABLE 25

Application	Rate lb PA/A	Average Increase	Number of Trials
Top-dressed/irrigated	1.06	2 tons/A	1
Side-dressed with UAN	2.12	6 tons/A	2

Sugar Cane

Results from non-replicated field trials show that sugar cane grown in the presence of polyaspartic acid plus fertilizer, when compared to sugar cane grown in the presence of fertilizer alone, demonstrates an average increase of 705 pounds of sugar per acre (Table 26).

TABLE 26

Application	Rate lb PA/A	Average Increase	Number of Trials
Knifed with fertilizer	2.12	694 lb sugar/A	1
2nd Year Stubble			
Knifed with fertilizer	2.12	518 lb sugar/A	1
Plant Cane			
Knifed with fertilizer	2.12	804 lb sugar/A	2

It therefore can be seen that the invention accomplishes at least all of its stated objectives.

EQUIVALENTS

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described specifically herein. Such equivalents are intended to be encompassed by the scope of the following claims.

What is claimed is:

1. A plant grown in the presence of a polyamino carboxylic acid, said plant characterized by one or more of the following: increased fruit load, increased yield, increased top growth and increased root growth when compared to another plant of the same variety which was not grown in the presence of said polyamino carboxylic acid.

2. The plant of claim 1 wherein the polyamino carboxylic acid is a poly (amino acid) being selected from the group consisting of: polyaspartic acid, polysuccinimide, polyglutamic acid, polyglycine, polylysine, a copolymer of cysteine and glutamic acid, and a terpolymer of cysteine, glutamic acid, and aspartic acid.

3. The plant of claim 1 wherein the polyamino acid is polyaspartic acid.

4. The plant of claim 1 further grown in the presence of fertilizer.

5. The plant of claim 1 wherein said increased top growth is demonstrated by one or more of the following: taller plant height, improved plant vigor, and advanced maturity.

6. The plant of claim 1 wherein the increased root growth is demonstrated by one or more of the following: longer tap root, more extensive lateral root system, more root hairs, and longer, thicker, more dense root system.

7. The plant of claim 1 wherein the increased fruit load is demonstrated by one or more of the following: increased quantity of fruit, enhanced quality, and increased fill of fruit.

8. The plant of claim 1 wherein the increased yield is demonstrated by one or more of the following: increased weight, increased quantity and increased size.

9. The plant of claim 3 wherein the polyaspartic acid or its analogue has an average molecular weight (MW) ≥ 1500 and is a non-chelating, non-aromatic polymer.

10. The plant of claim 1 wherein the plant is selected from the group consisting of: a plant which is a row crop, a plant which is a cash crop, and a plant which is a vegetable crops.

11. A corn plant grown in the presence of a polyamino carboxylic acid, said plant characterized by one or more of the following: increased fruit load, increased yield, increased top growth and increased root growth when compared to another plant of the same variety which was not grown in the presence of said polyorganic acid.

12. The corn plant of claim 11 further exhibiting one or more of the following characteristics: increased grain yield, increased silage yield, lower grain moisture at harvest, and increased plant vigor.

13. The corn plant of claim 11 wherein said increase in grain yield is in the range of about 5-61 bushels/acre.

14. The corn plant of claim 11 wherein the increased grain yield is in the range of about 15-41 bushels/acre.

15. The corn plant of claim 11 wherein the increase in silage yield is about 2 tons/acre.

16. The plant of claim 1 wherein the plant is soybean.

17. The soybean plant of claim 16 wherein the increased yield is in the range of about 1-10 bushels/acre.

18. The soybean plant of claim 16 wherein the increased yield is in the range of about 4-10 bushels/acre.

19. The plant of claim 1 wherein the plant is cotton.

20. The cotton plant of claim 19 wherein the increased yield is in the range of about 36-686 pounds lint/acre.

21. The cotton plant of claim 19 wherein the increased yield is in the range of about 227-415 pounds lint/acre.

22. The plant of claim 1 wherein the plant is winter wheat.

23. The winter wheat plant of claim 22 wherein the increased yield is in the range of about 1-11 bushels/acre.

24. The winter wheat plant of claim 22 wherein the increased yield is in the range of about 4-8 bushels/acre.

25. The plant of claim 1 wherein the plant is spring wheat.

26. The spring wheat plant of claim 25 wherein the increased yield is about 10 bushels/acre.

27. The plant of claim 1 wherein the plant is a vegetable plant.

28. The plant of claim 1 wherein the plant is selected from the group consisting of: sorghum, peanut, spring barley, sugar beet, and sugar cane.

29. The corn plant of claim 11 wherein the polyorganic acid is polyaspartic acid or its analogue and is presented to the plant at a rate of about 1.0 to about 2.5 pounds per acre.

30. The cotton plant of claim 19 wherein the polyorganic acid is polyaspartic acid or its analogue and is presented to the plant at a rate of about 2.0 to about 4.5 pounds per acre.

31. The vegetable plant of claim 27 wherein the polyorganic acid is polyaspartic acid or its analogue and is presented to the plant at a rate of about 2.0 to about 4.5 pounds per acre.

32. The plant of claim 22 wherein the polyamino carboxylic acid is polyaspartic acid or its analogue and is presented to the plant at a rate of about 1.0 to about 2.5 pounds per acre.

33. The corn plant of claim 11 wherein the polyaspartic acid is applied half of the rate at planting with a banded fertilizer and the other half of the rate with a side-dress fertilizer.

34. The cotton plant of claim 19 wherein the polyaspartic acid is applied half of the rate at planting with a banded fertilizer and the other half of the rate with a side-dress fertilizer.

35. The vegetable plant of claim 27 wherein the polyaspartic acid is applied half of the rate at planting with a banded fertilizer and the other half of the rate with a side-dress nutrients.

36. The winter wheat plant of claim 22 wherein the polyaspartic acid is applied about 1.0 to about 1.5 pound per acre with fertilizer in the fall and about 1.0 to about 1.5 pound per acre at top dress.

37. A plant produced by the method of: supplying to the plant a polyaspartic acid or its analogue either directly or hydrolyzed from polysuccinimide, wherein the polyaspartic acid or its analog is water soluble, has an average molecular weight (MW) ≥ 1500 and is a non-chelating, non-aromatic polymer that cannot be absorbed by the plant.

38. The plant of claim 37 wherein the polyaspartic acid or its analogue has an average molecular weight (MW) of about 2000 to about 100,000.

39. The plant of claim 37 wherein the polyaspartic acid or its analogue has an average molecular weight (MW) of about 3000 to about 5000.

40. A plant of a variety produced by the method of: growing said plant in the presence of a polyamino carboxylic acid, said plant having an improved characteristic when compared to another plant of said variety not grown in the presence of said polyorganic acid, wherein the improved characteristic is one or more of the following: increased top growth, increased root growth, increased fruit load and increased yield.

41. The plant of claim 40 further comprising the step of: growing said plant in the presence of fertilizer.

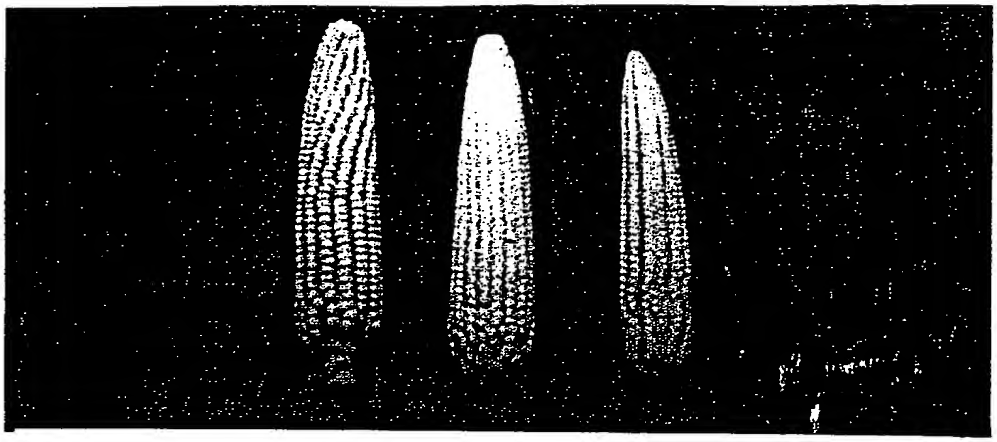


FIGURE 1

FIGURE 2

FIGURE 3

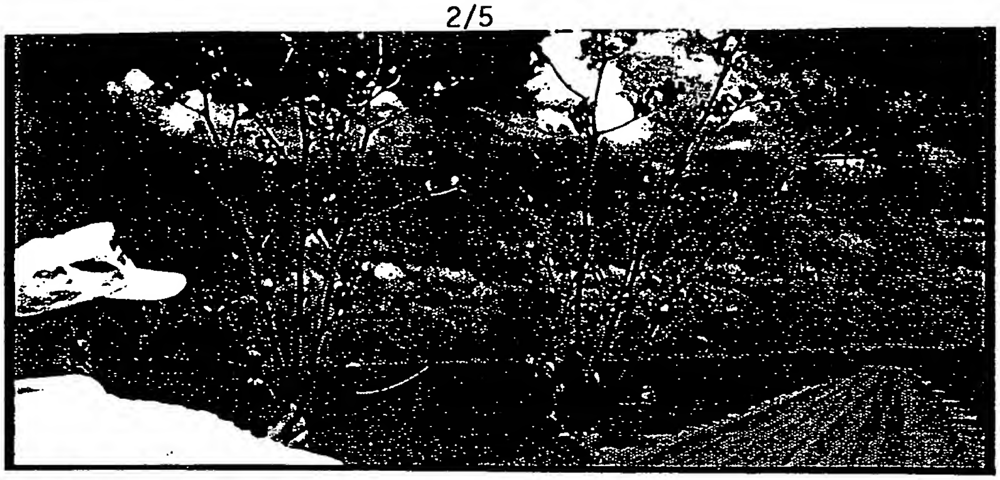


FIGURE 4

FIGURE 5

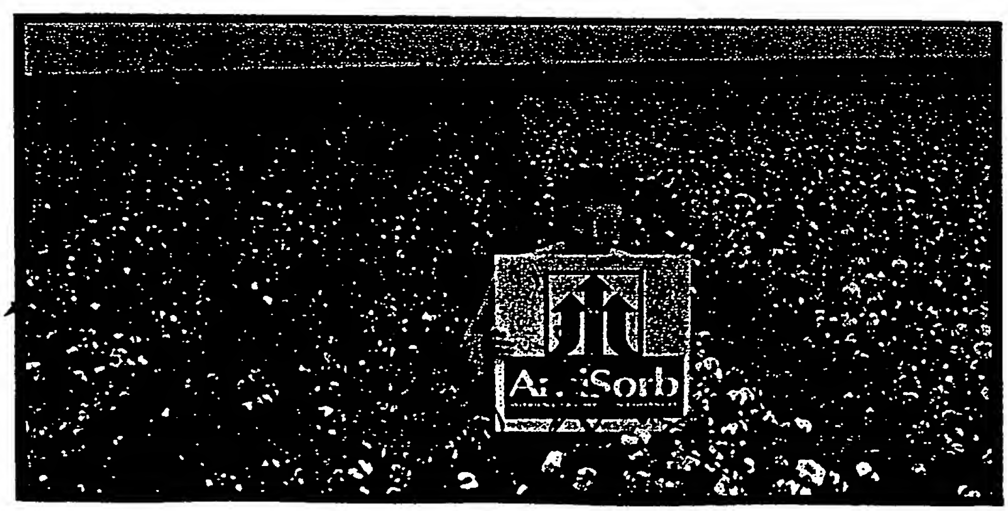


FIGURE 6

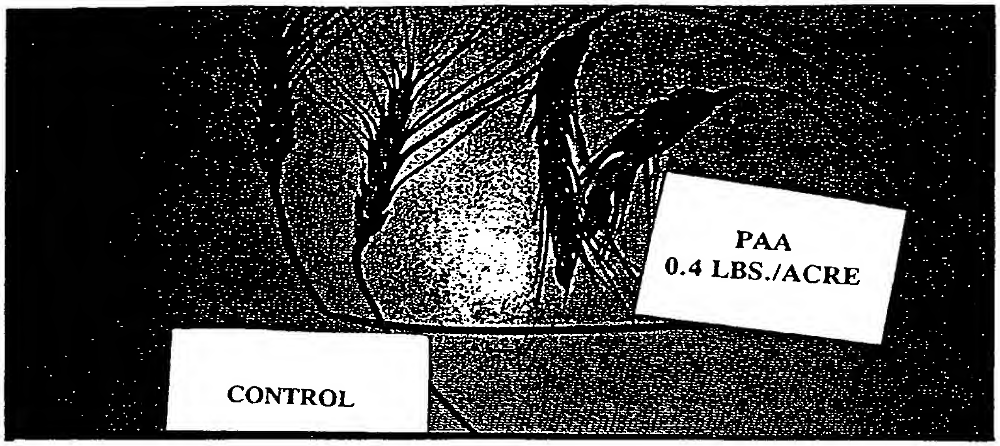


FIGURE 7

FIGURE 8

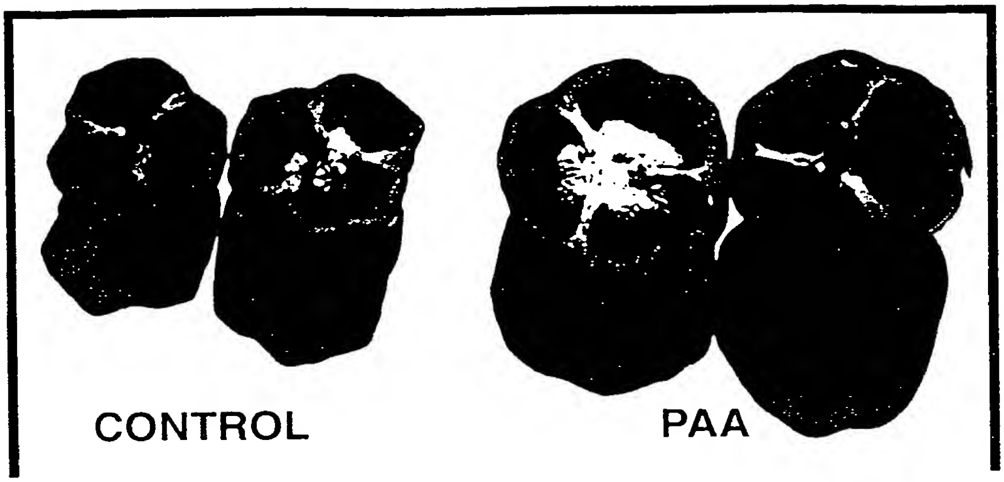


FIGURE 9

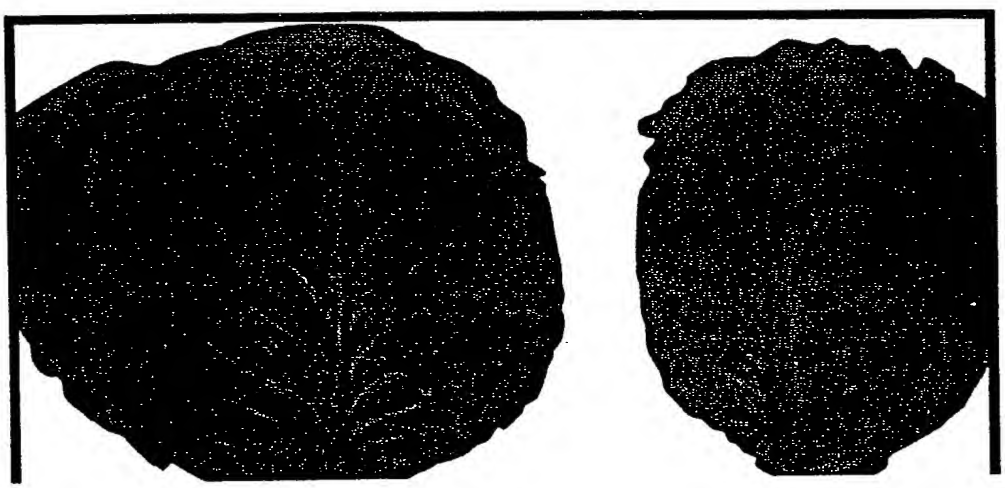


FIGURE 12

FIGURE 10

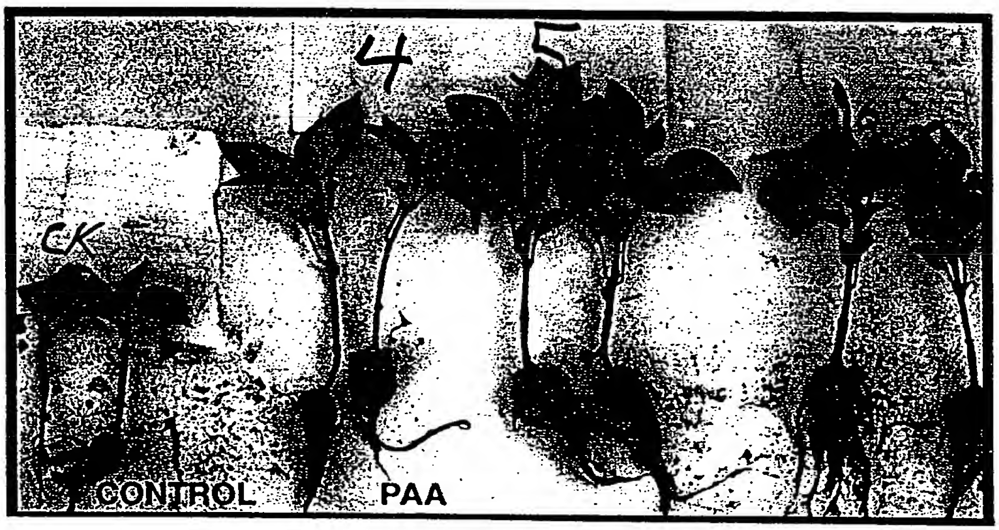


FIGURE 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/12926

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A01N37/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 37103 A (DONLAR CORP) 28 November 1996 (1996-11-28) claims 1,8,9,11; example 1	1-41
X	WO 94 09628 A (KINNERSLEY ALAN M ;KOSKAN LARRY P (US); STROM DAVID J (US); MEAH A) 11 May 1994 (1994-05-11) page 8, paragraph 6 -page 9, paragraph 1; claims 15,19	1-41
X	ROSS, R.J. ET AL: "Production and use of Thermal Polyaspartates" ABSTRACTS OF PAPERS AMERICAN CHEMICAL SOCIETY, vol. 213, no. 1-3, April 1997 (1997-04), XP002121694 abstract No. 089	1-41

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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Date of the actual completion of the international search	Date of mailing of the international search report
5 November 1999	22/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bertrand, F

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/12926

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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P,X	WO 98 30100 A (DONLAR CORP) 16 July 1998 (1998-07-16) page 17, paragraph 3; claims 1,4,7; example 10	1-41

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Information on patent family members

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PCT/US 99/12926

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